I.C. 6984R

JUNE 1939

UNITED STATES
DEPARTMENT OF THE INTERIOR
HAROLD L. ICKES, SECRETARY

BUREAU OF MINES
JOHN W. FINCH, DIRECTOR

INFORMATION CIRCULAR

MINERAL WOOL

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BY

J. R. THOENEN

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

MINERAL WOOL[1]

By J. R. Thoenen[2]

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[1] The Bureau of Mines will welcome reprinting of this paper provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 6984R."

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INTRODUCTION AND ACKNOWLEDGMENTS

In June 1929 the Bureau of Mines issued a 13-page information circular entitled "Mineral Wool," which was one of the first publications to present to the public some technical aspects of the mineral-wool industry. Since then several articles on the subject have appeared in the technical press as well as in publications of State organizations. Inquiries for information on mineral wool have continued to be received by the Bureau of Mines in large number, and in 1935 it was decided to make a field survey of the plants then producing and to collect therefrom technical data to be compiled in a paper for public distribution.

With the cooperation of the industry, this survey was made, and Information Circular 6984, Mineral Wool, was published in January 1938. The issue was exhausted after a few months, and requests for copies continued to come to the Bureau. As opportunity arose, further field studies were made in American as well as Canadian plants. The present circular contains the essential information in Information Circular 6984 together with data from later field studies.

The author is happy to express his appreciation of the cordiality with which he was received at all plants visited, the generous manner in which information was given him, and the willingness of all to cooperate with him. In any young industry such as this, progress is made largely by individual research and study carried on independently at local plants. Under such conditions, manufacturers are prone to guard their operating methods carefully and are extremely loathe to discuss them with outsiders. The writer is honored by the confidence placed in him by the producers who discussed these trade secrets freely, asking only that they be withheld from harmful publication. Curiously enough, certain practices held strictly confidential by one producer frequently were given freely for publication by another. This condition caused the author some concern, in that if information permitted by one but refused by another were published, he might be considered to have broken faith with the latter. To avoid this, the descriptions of technical practices have, in each instance, been specifically released by letter, and where a particular item has been considered confidential by one operator it has not been included unless released by two or more other operators. Therefore, if any operator reading this paper finds described therein any process which he considered confidential he may rest assured that at least two other plants were following the same practice and that both had released the information for publication.

DEFINITION

Mineral wool is a substance composed of very fine, interlaced mineral fibers having the appearance of loose wool or cotton. It is a fibrous, glasslike material composed principally of silicates of calcium and aluminum together with other minor constituents.

Mineral wool is a generic term covering a number of similar products differentiated chiefly by the raw materials from which they are made, as follows:

Rock wool, made from natural rock used alone or from various combinations of natural minerals.

Slag wool, made from iron, copper, or lead blast-furnace slag alone or mixed with fluxing materials.

Glass wool, made from silica sand, soda ash, and limestone with or without scrap glass or other materials.

In addition, there is another similar type of wool that, strictly, is neither of those mentioned but is a "mineral" wool in that it is made from manufacturers' waste materials (other than slag) combined with other mineral materials.

MARKETABLE FORMS AND USES

Mineral wool is marketed as loose or granulated wool in a variety of fabricated forms and, combined with other materials, as an insulating cement.

Loose Wool

Loose wool is the raw product as blown and without subsequent treatment. This is the material from which all mineral-wool products are made. It is used as insulation in new houses without further treatment.

Granulated Wool

Loose wool is run through granulators that break up the fibers and free them from the tiny globules or "shot." Freed from shot and rolled into small pellets 1/2 inch or less in diameter, the wool is known and sold as granulated wool. Its principal use in this form is as insulation for houses already built. It is blown into the spaces between wall studding or floor joists by compressed air.

Fabricated Forms

Bats

Loose wool mixed with suitable binders is compressed and cut to such thickness and shape as consumers may demand. In this form it is sold as bats and is used for insulating new houses by insertion in walls, floors, or roofs between studs, joists, or rafters. Bats are supplied with or without one or two paper covers, as desired. A similar product is made, in which the wool is rolled with paper between instead of being cut into rectangular shapes. This is known as roll wool.

Blankets

Loose wool, treated or untreated with suitable binders, is formed into blankets of various rectangular shapes and thickness and sewed between chicken wire, metal lath, paper, or other confining media. Blankets are used largely for insulation in annealing and baking ovens and metallurgical or chemical furnaces.

Blocks

Loose wool with suitable binders is compressed into blocks for use in refrigerator or stove insulation.

Pipe Covering

Bound, compressed, and formed to size, mineral wool is also made into pipe covering.

Insulating Cement

Loose wool combined with clay or bentonite and asbestos fiber is sold as an insulating cement for use in the joints between other fabricated forms or as a plastic insulation around irregularly shaped objects.

SOURCES OF INFORMATION

The material from which this paper is compiled was gathered in the field by the author during personal visits to manufacturing plants scattered over the United States and Canada. This field work covered the calendar year 1936, the first 6 months of 1937, and the fall of 1938. Plant studies were made as opportunity arose and when other duties did not interfere. At the time this manuscript was completed the author had a list of 71 producing companies operating 82 plants. In addition, 10 companies were acting as distributors but did not manufacture. The author personally visited and collected data from 40 plants.

HISTORY OF THE INDUSTRY

It is reported[3] that mineral wool was produced in Wales, England, in 1840, shortly thereafter in Germany, in 1888 in Cleveland, Ohio, and at Salem, Va., in 1890. The industry was started in Indiana in 1897 by C. C. Hall. In 1928 seven producing companies were operating eight plants. Production for 1928 was estimated by the author as approximating 50,000 tons.[4] Since that time the number of producing firms has increased, and in 1936 production was estimated at 500,000 tons, including all classes - rock, slag, and glass wool. The 1938 production is estimated to have been 400,000 tons, or 20 percent below the estimate for 1936. Production for 1939 is expected to increase with the increase of residential construction commonly forecast by various agencies.

ESTIMATED PRODUCTIVE CAPACITY

It is estimated that there are at present (1939) in the United States the equivalent of 160 cupolas in operation manufacturing mineral wool. Cupola capacity, in tons of loose wool per 24 hours, is estimated to range from 5 to 20 tons and to average 10 tons. From this, the present annual capacity is estimated to be nearly 600,000 tons of loose wool, or 50 percent above estimated production for 1938. Plants representing one-third the entire capacity reported the distribution of products made as, roughly, one-third loose wool, one-third granulated wool, and one-third fabricated products.

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[3] Stone, The Origin of Rock Wool: Vol. 57, No. 12, December 1936.

[4] Thoenen, J. R., Mineral Wool: Bureau of Mines Inf. Circ. 6142, 1929, 13 pp.

PLANT DESCRIPTIONS

The following more- or less-detailed descriptions of individual plants cover some but not all of those visited by the author. In no instance are complete details given because of the confidential nature of the processes.

In view of the many items of a confidential nature involved, the author does not feel it would be ethical for him to discuss individual plants or processes in detail and has therefore merely presented the following descriptions authorized for publication by the manufacturers.

Plant 1

Raw material:

Lead slag, iron slag, shale, and siliceous gravel, proportioned by bulk and fed alternately with coke in layers 8 to 10 inches thick.

Recovery:

3 tons raw material = 2 tons loose wool.

Fuel ratio:

1 coke to 3 raw material.

Plant capacity:

200 to 300 tons loose wool per month.

Cupolas:

2 - diameter 40 inches, height 8 feet.
Temperature - melting, 2,600° to 2,700° F.
Water jackets - full height of cupola; water pressure, 35 pounds per square inch.
Blast - supplied by blower at pressure of 12 to 16 ounces.
Tap hole - 1 each cupola; waterjacketed cast iron.

Slag stream:

Length, 10 inches.

Steam jet:

V-type nozzle placed to receive slag stream on one leg.
Steam pressure, 110 pounds gage.

Oil:

Light paraffin oil fed through steam jet.

Wool rooms:

24 by 45 feet in horizontal section.
Wool stream is directed to corner of alternate rooms, causing shot to collect along wall.

Granulator:

Trommel type, 48-inch diameter, 12 feet long, slope 1 inch per foot, 25 r.p.m. Trommel is of local construction with seven 48-inch-diameter iron-spoke pulleys covered with 4-mesh screen. Inside, parallel to the axis, are six 2- by 4-inch timbers fastened to the pulleys at equal peripheral intervals. Each timber contains protruding nails pointing to the center. These act as combs, as the wool passes through, and separate fiber from shot.

Plant 2

Raw material:

Lead slag, silica rock, limestone.
Silica rock ranges from 90 to 93 percent SiO_2.
Limestone averages 97 percent $CaCO_3$.
Chemical analysis of slag and wool:

	Slag, percent	Wool, percent
SiO_2	24-25	40
CaO	10-12	10
Al_2O_3	8	7
FeO	40-42	30

Recovery:

7 tons raw material = 6 tons loose wool.

Fuel ratio:

1 coke to 6 raw material.

Plant capacity:

2,800 tons loose wool per month.

Cupolas:

4 - diameter 48 inches, height 9 feet.
Temperature - melting, 2,100° F; blowing, just above freezing temperature.
Water jackets - full height.
Tap hole - 3 each cupola, refractory brick with cast-iron bed plates.

Reverberatory furnace:

1 - 9 feet wide, 20 feet long, 3 feet floor to top of arch.
Temperature - 2,200° F. as determined by thermocouple in furnace wall.
Water jackets - none.
Tap hole - 6 in front end of furnace.
Fuel - natural gas.

Slag stream:

Diameter, 1/4 to 1/2 inch; length, 6 to 8 inches.

Steam jet:

V-type nozzles, legs 1 1/2 inches long.
Steam pressure, 40 to 80 pounds gage.

Wool rooms:

6 to 8 feet wide by 50 feet long by 20 feet high.
48-inch, 4- to 5-mesh screen conveyor floor.

Granulator:

Hammer-mill type.

Shot removal:

Trommel, 48-inch diameter, 5-mesh screen.
Granulated wool containing shot is also dropped vertically to an inclined metal plate. On impact, the shot bounces to one compartment while the wool slides to another.

Wool fiber:

Diameter, 3 to 5 microns.

Plant 3

Raw material:

Oil firebrick, dolomite, limestone, fluorspar.
Approximate analysis of cupola charge.

	Percent
SiO_2	36
Al_2O_3	24
MgO	2
CaO	37

Recovery:

2,000 pounds raw material = 1,350 pounds loose wool.

Fuel ratio:

1 coke to 3 raw material.

Plant capacity:

10 tons loose wool daily.

Cupolas:

1 - diameter 43 inches, height 16 feet.
Temperature - melting, 2,550° to 2,600° F.
Water jacket - lower 8 feet.
Tap hole - 1 in cupola, fire clay.

Slag stream:

Diameter, 1/4 to 3/4 inch; length 8 inches.

Air jet:

Two converging slots 1-3/4 inch long separated 1 inch at top and 1/4 inch at bottom.
Air pressure, 90 to 110 pounds gage.
Air used, 700 cubic feet per minute.

Wool room:

5 by 75 by 35 feet high. Metal-covered-slat conveyor floor.

Granulator:

Hammer-mill type.

Shot removal:

Trommel, 48 inch by 16 feet; slope, 1 foot in 16 feet; 20 r.p.m.; covered with 4-mesh screen.

Plant 4

Raw material:

High-silica lead slag.

Recovery:

2,000 pounds of raw material = 1,500 pounds loose wool.

Fuel ratio:

1 coke to 4 or 5 slag.

Plant capacity:

5 tons loose wool per 20 hours.

Cupola:

1 - diameter 36 inches, height 12 feet.
Temperature - melting 3,400° F.
Water jackets - 4-inch full height.
Tap hole - 1 in cupola; firebrick and clay.

Slag stream:

Diameter 1/4 inch; length 6 inches.

Steam jet:

V-type nozzle with 1-1/2-inch legs at 30° angle. There is a small round orifice 1/2 inch above the apex of the V. The slag stream is directed to this central opening.
Steam pressure, 100 pounds gage.

Oil:

None used.

Granulator:

Grain-chopper type.

Shot removal:

Conical screen, 18 and 60 inches by 10 feet long covered with 4-mesh wire cloth, 25 r.p.m.

Plant 5

Raw material:

Iron slag, dolomite.

Partial chemical analysis:

	Slag, percent
SiO_2	40
Al_2O_3	12
CaO	27
MgO	16
Other	5

Recovery:

1,000 pounds raw material = 900 pounds loose wool.
900 pounds loose wool = 765 to 810 pounds granulated wool.

Fuel ratio:

1 coke to 4 raw materials.

Plant capacity:

36 tons loose wool per 24 hours.

Cupolas:

3 - diameter 48 inches, height, 8 feet.
Temperature - melting 2,800° F., blowing 2,600° F.
Water jackets full length, water pressure, 33 pounds gage.
Tap hole - 1 each cupola.

Slag stream:

Diameter, 3/8 inch; 2 from each cupola.

Steam jet:

V-type nozzle with 3-inch legs at 30° angle.
Steam pressure, 100 pounds gage.

Wool room:

Room is insulated with wool and is 30 inches wide, 24 feet long, and 18 feet high. The floor of the room is a 6-mesh wire-cloth conveyor.

Granulator:

Trommel, 30-inch diameter by 18 feet long; slope 1 to 12, r.p.m. 60.
The initial 4 feet is encased in sheet metal and contains a single helical feeder. The remaining 12 feet is the granulator proper. The central shaft has beater paddles set on 24-inch centers along the shaft and alternated with iron rods between the paddles. Both rods and paddles are set at random radial angles and are 10 inches

long. The paddles are 3 by 3 inches in size and pitched in a helical path. The bottom casing of the granulator is perforated and shot is removed here.

Shot removal:

Some shot is removed from the granulator. The larger portion is removed in a second trommel following the granulator. This is 36 inches in diameter by 6 feet long, set on a slope that can be varied from 1 to 3 inches per foot. The screen is 4 mesh. The granulated wool is blown from the last screen by compressed air to a chamber. This method of conveyance separates the wool fibers from remaining shot.

Wool fiber:

Diameter, 3 to 4 microns.

Plant 6

Raw material:

Iron slag.
Analyses of slag and wool:

	Slag, percent	Wool, percent
SiO_2	36.52	36.52
Al_2O_3	12.61	14.66
CaO	41.56	40.76
MgO	6.24	5.96
FeO	1.69	1.31
MnO_2	.70	.52
CaS	1.84	1.69

Cupolas:

6 - diameter 36 inches, height 7 feet 6 inches.
Temperature - melting 3,200° F., blowing 2,800° F.
Water jackets - 3-inch full length.
Water used - 200 gallons per minute.
Blast - 10- to 12-inch water gage.
  Air used - 1,000 cubic feet per minute per cupola.
  Tuyeres - 13 inches above base.

Steam jet:

V type with legs 1-3/4 inch long, separated 1 inch at top and 0.03 inch wide.
Steam pressure, 95 pounds gage.

Wool room:

12 by 50 by 15 feet high. Cupola blows to one of two rooms alternately. All rooms are ventilated through the roof by a special process. One room has a conveyor floor 9 feet wide. The rest are cleaned by hand with pitchforks.

The wool blanket emerging from the room on the conveyor passes through a set of seven circular disk saws, which cut it into longitudinal strips. The strips are cut transversely into blocks by a hand-operated knife.

Granulator:

Trommel type; diameter 6 feet, length 16 feet, slope 6 inches in 16 feet.

Screen, 8-mesh, speed 13 r.p.m. Inside, affixed to the central shaft, are a number of sets of six 1/2-inch rods 20 inches long fixed radially at 6-inch intervals along the shaft. Between these sets others are fixed to the interior of the granulator shell. There are 8 rods in these outer sets. The ends of the shaft and shell rods overlap about 4 inches.

Wool fiber:

Average thickness, 3 microns.

Plant 7

Raw materials:

Copper slag, limestone, silica sand.

As fed to the melting furnace, the slag and limestone are crushed to pass 4 mesh and the sand to pass 30 mesh.

Sand averages 92 percent silica and the limestone 50 percent CaO.

Typical analyses of the slag are:

	Maximum, percent	Minimum, percent
SiO_2	38	27
FeO	40	35
CaO	1.5	.4
Al_2O_3	14	3

Recovery:

1,000 pounds raw material = 800 pounds loose wool.
800 pounds loose wool = 500 pounds granulated wool.

Fuel ratio:

50 to 60 gallons of fuel oil per hour is used for firing.

Plant capacity:

65 tons loose wool per 24 hours.

Cupolas:

This plant uses 3 reverberatory furnaces 9 feet wide, 21 feet long, and 3 feet from floor to top of arch.

Temperature - melting and blowing temperature are maintained at 2,400° F., as determined by thermocouples in the furnace walls.

Water jackets - none.
Tap hole - there are six tap holes in the front end of each furnace.

Slag stream:

The slag streams pass over special nosepieces or lips and drop 6 inches to compressed-air jets.

Air jets:

V type with 1-1/2-inch legs.
Air pressure, 50 pounds gage.

Wool rooms:

50 feet long, 30 feet high; 7-1/2 feet wide at top with movable side walls, such that the floor can be adjusted to a width of from 18 to 48 inches. Rooms are built of 4-mesh wire cloth open to the atmosphere. An exhaust-air conduit 36 inches in diameter in each roof draws fly wool to a settling chamber.
Room floors are 4-mesh screen conveyors.

Shot removal:

Trommel type, 4 feet diameter, covered with 5 by 5 mesh wire cloth. Shot passing the screen is returned to the furnace.

Plant 8

Raw materials:

Iron slag obtained from various sources and mixed.
Approximate analysis of feed:

	Percent
SiO_2	38
Al_2O_3	10-12
CaO	35
MgO	10

Recovery:

1,000 pounds raw material = 850 pounds loose wool.
850 pounds loose wool = 590 pounds granulated wool.

Fuel ratio:

1 coke to 4 raw material.

Plant capacity:

25 tons loose wool per 24 hours.

Cupolas:

2 - diameter 45 and 36 inches, both 7 feet high.
Temperature - melting 2,900° F., blowing 2,600° F.

Waterjacketed full height. Hydrant pressure.
Blast air is fed at 11-inch water pressure through tuyeres 20 inches above bottom of cupolas. Quantity of air used is 700 cubic feet per minute to each cupola.

Slag stream:

Slag from cupola passes over a cast-iron shelf, which divides it into two streams, each falling to separate steam jets.

Steam jets:

V-type nozzles with legs 2 inches long, 0.051 inch wide, and separated 1 inch at top. Steam pressure, 100 pounds gage.

Oil:

Fed between steam jet and wool room at 1-3/4 gallons per ton of of loose wool.

Wool rooms:

60 feet long, 10-1/2 feet high, and 8 feet wide at top with lower portion tapered to 15-inch width at bottom. Floor is 4-mesh screen conveyor traveling 10 feet per minute.

Granulator:

Trommel-type, 36 inches wide, 8 feet long, revolving 3/4 r.p.m.
Covered with 6-mesh wire cloth.

Plant 9

Raw materials:

Calcareous shale from four different beds tempered with sandstone.
Cupola charge is 245 pounds shale, 50 pounds sandstone.

Recovery:

1,000 pounds raw materials = 600 to 650 pounds loose wool.
600 to 650 pounds loose wool = 400 pounds granulated wool.

Fuel ratio:

1 coke to 3 raw materials.

Plant capacity:

8 tons loose wool per 24 hours.

Cupola:

1 - diameter 42 inches, length 8 feet.
Temperature - melting 2,800° to 3,000° F., blowing 2,500° F.
Water jackets - 4-inch, full length.
Blast air - pressure 8 ounces, entering 12 inches above cupola bottom.
Tap hole - 1 in cupola, fireclay.

Slag stream:

Passes over waterjacketed cast-iron lip. Stream, 1/4-inch diameter, 6 inches long.

Steam jet:

V type with legs 1-1/2 inches long and 0.03 inches wide, spread 1 inch at top. Nozzle face curved on 2-inch radius.

Oil:

Fed 6 to 12 inches beyond steam jet at 1/4 to 1 gallon per ton loose wool.

Wool room:

50 feet long, 14 feet high, 5 feet wide.
Floor is slat conveyor traveling from 6 inches to 2-1/2 feet per minute. Compression roll at end of room weighs 200 pounds. Blankets made 3 inches thick for loose and granulated wool and 3/4 inch thick for stove insulation.

Granulator:

Feed-chopper type.

Shot removal:

Trommel, 36-inch diameter, 10 feet long, slope 24 inches to 10 feet, speed 15 r.p.m.

Plant 10

Raw material:

Indiana wool rock, dolomite.

Typical analyses are:

	Wool rock, percent		Loose wool, percent	
	1	2	1	2
SiO_2	16.0	32.0	41.0	41.0
CaO	43.0	18.0	28.0	30.0
MgO	6.0	13.0	16.0	5.0
CO_2	26.0	20.0	--	--
Al_2O_3	5.3	9.4	10.0	21.0
Fe_2O_3	2.0	5.0	1.6	--
K_2O	--	--	3.6	--

Recovery:

100 pounds raw materials = 70 pounds loose wool.
70 pounds loose wool = 50 pounds granulated wool.

Fuel ratio:

Variable with type of wool being blown.

Plant capacity:

112 to 126 tons loose wool per 24 hours.

Slag stream:

Length, 6 to 10 inches.

Steam jet:

V type with legs 2-1/4 inches long, 3/16 inch wide.
Steam pressure, 100 pound gage.

Wool room:

Ventilated through roofs. Floors are conveyors operating at from 1 to 10 feet per minute. Rooms supplying wool for fabrication into bats have conveyors passing through equipment beyond the room for further treatment and drying. Heat to this equipment is supplied by natural gas.

Plant 11

Raw material:

Shale, sandstone.

Typical analyses, shale, sandstone, and wool, are:

	Shale, percent	Sandstone, percent	Wool, percent
SiO_2	8.0	86.6	40.3
Al_2O_3	3.0	3.6	7.6
Fe_2O_3	.6	1.7	1.2
CaO	29.5	2.0	31.8
MgO	16.4	.7	18.2
CO_2	41.1	2.1	--

Cupola charge is approximately:

Shale,	400 pounds
Sandstone,	40 pounds

Fuel ratio:

1 coke to 1.25 raw material.

Cupola:

1 - diameter 66 inches, height 9 feet.
Water jacket - 6 inches full length.
Tap hole - 1 - firebrick.

Steam jet:

V type with legs 2 inches long, 1/32 inch wide, spread 1 inch at top.
Steam pressure, 100 pounds gage.

Wool rooms:

60 feet long, 20 to 35 feet high, and 30 feet wide; cupola blows to one of two rooms alternately.

Granulator:

Feed-chopper type, speed 350 r.p.m.

Shot removal:

Trommel, 60 inches diameter, 10 feet long, speed 125 r.p.m., slope 4 inches in 10 feet, covered with 3/16-inch wire cloth.

Plant 12

Raw material:

Iron slag and feldspar.
Typical analyses of slag and wool:

	Slag, percent	Wool, percent
SiO_2	35.75	41.0
Al_2O_3	11.5	12.3
CaO	36.25	34.5
MgO	12.9	9.6
Fe_2O_3	1.5	1.3

Fuel ratio:

1 coke to 3 raw materials.

Cupolas:

3 - two 54 inches diameter x 10 feet high
one 48 inches diameter x 10 feet high.
Water jackets - 6 inch full length.
Air blast 1,000 to 1,200 cubic feet per minute.
Tap holes - 2 in each cupola in fire clay.
Temperature - melting, 2,700° F.; blowing 2,200° F.

Slag streams:

Diameter - 1/2 inch, tapering to point at which it is blown.
Length - 6 to 10 inches depending on type of wool blown.

Steam jet:

V type with legs 1-1/2 inches long, spread 1 inch at top.
Steam pressure 125 pounds gage.

Oil:

Fed 2 feet beyond steam jet. Quantity ranges from 1/2 to 2 percent of wool by weight depending on type of wool made.

Wool rooms:

50 feet long, 40 feet high, ventilated at top; having slat type conveyor 6 feet wide.

Granulator:

Feed shredder type with variable chopping action. Speed 1,125 r.p.m.

Shot removal:

Trommel 60 inches diameter, 10 feet long, slope 6 inches in 10 feet, speed 50 r.p.m., 8 mesh screen.

Plant capacity:

27 tons loose wool per 24 hours.

Recovery:

4-3/4 tons raw material = 4 tons loose wool
4 tons loose wool = 3 tons granulated wool

Plant 13

Raw materials:

Quarry waste, clay.
Quarry waste is dolomite washings from concrete aggregate.
Both materials are briquetted, using either the auger or dry-press method.
Typical analysis of clay:

	Percent
SiO_2	58.3
Al_2O_3	30.23
Fe_2O_3	2.27
CaO	4.30
MgO	2.89
K_2O	.33
Na_2O	1.05

Cupola charge is 2 dolomite to 1 clay.

Recovery:

100 pounds raw material = 50 pounds loose wool.
50 pounds loose wool = 25 pounds granulated wool.

Fuel ratio:

1 coke to 2-1/2 raw materials.

Plant capacity:

17 tons loose wool per 24 hours.

Cupolas:

2 - diameter 36 inches, height 10 feet.
Temperature - blowing, 2,600° to 2,700° F.
Water jackets - 4-inch, full length.
Air blast - pressure 2 to 3 inches water. Air enters 24 inches above cupola bottoms.
Tap hole - fireclay.

Slag stream:

Drawn over cast-iron lip and split to two streams 1/4-inch diameter and 3 inches long.

Steam jet:

V type with legs 2 inches long and 0.046 inch wide, spread 1 inch at top.
Steam pressure, 85 to 100 pounds gage.

Oil:

Fed 8 to 10 inches beyond steam jet at rate of 1-1/2 gallons per ton loose wool.

Wool rooms:

40 feet long, 12 feet high, and 6 feet wide. Ventilated through roof.

Granulator:

Grain-thresher type.

Shot removal:

Trommel-type, 48 inches diameter, 10 feet long, covered with 8-mesh wire cloth, speed 40 r.p.m.

Plant 14

Raw material:

Dolomite tempered with a local siliceous slate.
Typical analysis:

	Dolomite, percent	Slate, percent
SiO_2	0.64	73.05
Fe_2O_3	.56	4.20
Al_2O_3	.50	13.90
CaO	30.63	--
MgO	21.59	--

Recovery:

1,000 pounds raw material = 650 pounds loose wool.

Fuel ratio:

1 coke to 1 stone.

Cupolas:

12 - water jacketed.
Blowing temperature - 2,550° F.
Cupola capacity - 7-1/2 tons per 24 hours.

Slag stream:

3/8 to 1/2 inch in diameter.
Drops 6 inches to steam jet.
Steam pressure, 100 pounds.

Wool room:

5 to 6 feet wide, 50 feet long, and 24 feet high.

Slat and wire-mesh conveyor floors traveling 6 to 24 inches per minute, with some arranged to pass through driers heated by fuel oil and others to deliver wool without drying.

Ventilated through top, where provision is made for collecting fly wool.

Oil:

Light paraffin oil allowed to drip to the wool stream.

Granulators:

Grain-thresher type.

Plant 15

Raw material:

Wool rock, dolomite.

Typical analyses are:

	Wool rock, percent	Dolomite, percent	Wool, percent
SiO_2	35.80	0.38	41.16
R_2O_3	13.00	.60	13.66
CaO	16.60	32.75	25.61
MgO	10.90	19.60	16.30

Cupola charge is: Wool rock, 975 pounds.
Dolomite, 225 pounds.

Recovery:

100 pounds raw material = 70 pounds loose wool.
70 pounds loose wool = 47 pounds granulated wool.

Fuel ratio:

1 coke to 3 raw material.

Cupolas:

2 - diameter 54 inches, height 8 feet.
Water jackets - 6-inch full length.
Tap hole - 2 each cupola, fireclay.

Slag stream:

Diameter 3/8 inch, length 6 inches.

Plant capacity:

Fourteen tons per cupola daily.

Steam jet:

V type with legs 1-3/4 inches long and 1/16 inch wide, spread 1 inch at top.
Steam pressure, 100 pounds gage.

Oil:

Fed at rate of 1 gallon per ton loose wool.

Wool rooms:

55 feet long, 24 feet high, 7 feet wide.
Ventilated through roof. The floor is a conveyor operated at a speed of 1 to 4-1/2 feet per minute for bat wool and 1-1/2 to 3 feet per minute for loose or granulated wool.

Plant 16

Raw material:

Shale from three different beds, silica sand.
Typical analyses, in percent, are:

	Shale			
	Olive green	Blue	Yellow	Wool
SiO_2	8.7	41.5	46.4	42.1
Al_2O_3	1.2	8.9	10.3	11.1
Fe_2O_3	1.1	3.3	3.8	2.5
CaO	29.8	13.3	11.2	27.3
MgO	16.7	8.8	7.6	15.8

Cupola charge consists of:

	Pounds
Shale:	
Olive green	150
Blue	54
Yellow	36
Sand	12

Recovery:

14 tons raw material = 6 tons loose wool.
6 tons loose wool = 4.5 tons granulated wool.

Fuel ratio:

1 coke to 1.46 raw material.

Plant capacity:

12 tons loose wool per 24 hours.

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Cupola:

Two.
Waterjacket is integral with firebox of 30-inch tubeless steam boiler mounted on top of cupola.
Blast air enters cupola 24 inches above base.
Tap hole - 1 - fireclay.

Slag stream:

Slag passes over cast-iron lip.
Steam pressure, 100 pounds gage.

Steam jet:

V shaped, but is composed of a number of 1/8-inch round holes in the shape of a V with legs 2-1/2 inches long, separated 1-1/4 inches at top.

Oil:

Fed 18 inches beyond steam jet at rate of 1 gallon per ton of loose wool.

Wool room:

6 feet wide with conveyor floor.
Wool blanket is marked by revolving disks and cut to bat size by hand over wooden templates.

Granulator:

Conical screen 2 and 3 feet in diameter by 8 feet long covered with 4-mesh wire cloth, speed 25 to 30 r.p.m.

Plant 17

Raw material:

Wool rock and dolomite.
The wool rock is from two different beds.
Typical analyses are:

	Yellow rock, percent	Gray rock, percent	Dolomite, percent	Wool, percent
SiO_2	41.6	35.3	6.4	46.5
Al_2O_3	8.7	8.2	1.7	17.96
Fe_2O_3	1.9	2.0	.7	--
CaO	13.6	15.5	28.8	16.47
MgO	9.9	11.0	19.4	10.0
CO_2	20.3	23.0	42.4	--

An average cupola charge is: Wool rock, 34 pounds
Dolomite, 6 pounds

Recovery:

3,300 pounds raw material = 2,000 pounds loose wool.
2,000 pounds loose wool = 1,400 pounds granulated wool.

Fuel ratio:

1 coke to 4 raw material.

Plant capacity:

24 tons loose wool per 24 hours.

Cupolas:

2 - diameter 60 inches, height 8 feet.
Temperature - blowing 2,800° F.
Water jackets - 6-inch, full length.
Tap hole - 1 each cupola, fireclay.

Steam jet:

V type with legs 1-7/8 inches long, 0.03-inch wide, spread 1 inch at top.

Oil:

Fed at steam jet at rate of 10 gallons per 12 tons loose wool.

Wool rooms:

55 feet long, 18 and 22 feet high, and 6 feet wide. Two rooms serve one cupola alternately. One room has conveyor floor. All are ventilated through louvres in the roof.

Granulator:

Clover huller type, speed 730 r.p.m.

Shot removal:

Vibrating screen 3-1/2 by 6 feet, flat, inclined 4 inches in 6 feet, vibrated 250 times per minute through 2-inch throw.
Screen cloth, 6 mesh.
Stationary screen, 6-mesh cloth, inclined 45°. Slope is changed to change size of wool nodules.

Plant 18

Raw material:

Wool rock and limestone.
Typical analyses are:

	Limestone, percent	Wool rock, percent	Wool, percent	
			1	2
SiO_2	0.9	43.2	36.21	41.04
Fe_2O_3	.16	1.6	.4	13.6
Al_2O_3	.32	14.0	13.16	
CaO	53.3	27.5	30.44	32.7
MgO	1.77	11.6	17.6	9.4
S	-	-	.5	.01

Cupola charge is: Wool rock, 1,100 pounds.
Limestone, 400 pounds.

Recovery:

100 pounds raw material = 65-75 pounds loose wool.
65-75 pounds loose wool = 55-60 pounds granulated wool.

Fuel ratio:

1 coke to 3 raw materials.

Plant capacity:

90 to 120 tons loose wool per 24 hours.

Cupolas:

6 - diameter 50 inches, height, 8 feet.
Water jackets - 6-inch, full length.
Air blast - equipped with thermostat to insure constant oxygen supply irrespective of barometric pressure.
Tap hole - 1 each cupola, fireclay.

Slag stream:

Stream split to two, each 1/2-inch diameter and 8 inches long.

Steam jet:

V type with legs 2 inches long, 3/16 inch wide, spread 1-1/4 inch at top.
Steam pressure, 85 pounds gage.

Oil:

Fed 18 inches beyond steam jet at 1-1/2 gallons per ton of loose wool.

Wool room:

60 feet long, 20 feet high, 8 feet wide.
Metal-covered wood-slat conveyor floors operating at 20 feet per minute; one room serves two cupolas.
Wool blanket from rooms passes through dryers. Wool is dried by air without heat.
Wool blankets are cut to bat size by toothed circular disk saws and by an automatic cut-off saw of same type.

Granulator:

Grain-shredder type.

Shot removal:

Trommel, diameter 36 inches, length 8 feet, speed 30 r.p.m.

Plant 19

Raw materials:

Scrap metal and limestone.
Customary cupola charge is:

	Pounds
Coarse scrap and residue	700
Sintered fines	300
Limestone	50
Brass scrap	125

100 charges are sent to cupola per 24 hours.

Recovery:

67.5 tons raw material = 5 to 10 tons loose wool.
100 pounds loose wool = 50 pounds granulated wool.

Fuel ratio:

1 coke to 9.4 cupola charge.

Plant capacity:

5 to 10 tons loose wool per 24 hours.

Cupola:

1 - 42-inch-diameter base, 60-inch-diameter top, 10 feet high.
Temperature - melting 2,300° F., blowing 2,500° F.
Water jackets full length.
Air-blast pressure, 1-1/2 pounds gage.
Tap-hole - 1 in cupola.

Slag furnace:

4 by 7 feet by 3-1/2 feet high. Reheating furnace receiving slag from cupola for reheating before blowing to wool.
Furnace is heated by oil, using 8 to 10 gallons per hour.
Slag discharges over a baffle at a rate depending upon the rate of flow from the cupola.
The slag flows through an open trough, in the bottom of which is a 3/4-inch hole.

Slag stream:

The slag from the hole in the trough falls to the surface of a wheel revolving on a vertical shaft at 1,800 r.p.m. (Excess slag passes over and discharges from the trough to running water, where it is granulated.) The revolving wheel resembles a bevel gear from which the teeth have been machined leaving a smooth face at an angle of 45°.
From the face of the wheel the slag stream is thrown 1 to 3 inches to the steam jet. The direction of projection of the slag from the wheel is at an angle of 90° with the direction of the steam jet.

Steam jet:

The steam jet consists of three 2-inch slots 1/16 inch wide, arranged so that the center slot is vertical, below and above which the other two form an open U turned so the open side received the slag.

Oil:

Fed at the rate of 1 gallon per ton of loose wool.

Wool room:

Wool is collected on a conveyor operating beside an 8-foot partition. Light, loose wool floats over this partition and is bagged separately.

Granulator:

Feed-chopper type.

Shot removal:

Trommel, 36 inches in diameter, 15 feet long, covered with 8-mesh wire screen except for terminal 18 inches, which has 3/4-inch-square openings. Shot is removed through the 8-mesh screen to a conveyor, which discharges to a stream of water in a trough leading to a pit, from which it is pumped to the slag dump by a centrifugal pump.
Stray lumps are rejected at end of screen. The granulated wool falls to a concrete floor, where it is picked up and blown to a storage bin by compressed air.

Plant 20

Raw material:

Iron slag and silica rock.
Partial analysis of the slag is:

	Percent
SiO_2	32
CaO	28
MgO	17

The wool contains from 38 to 39 percent silica.

Recovery:

100 pounds of raw material = 85 pounds loose wool.
85 pounds loose wool = 70 pounds granulated wool.

Fuel ratio:

1 coke to 2-1/2 raw material.

Plant capacity:

9 tons loose wool per 24 hours.

Cupola:

1 - diameter 28 inches, height 8 feet.
Temperature - blowing 2,600° F. for loose wool, 2,850° F. for granulated wool.
Tap hole - 1 in cupola, fireclay.

Slag stream:

Drops 4 inches to cast-iron lip, where it splits to two streams, each falling 6 inches to steam jets.

Steam jet:

U shape, vertical slots 2 inches long, horizontal slot 3/4 inch, and all 1/16 inch wide.

Wool room:

37 by 10 by 7 feet with galvanized screen-conveyor floor.

Plant 21

Raw material:

Limestone, dolomite, and sandstone with chemical analyses, in percent, as follows:

	Stone			Wool	
	No. 1	No. 2	No. 3	No. 1	No. 2
SiO_2	0.45	17.71	93.35	44.76	43.04
Al_2O_3	.52	5.0	3.58	6.85	6.80
Fe_2O_3				1.37	1.05
$CaCO_3$	98.31	44.28	.24	38.85	42.04
MgO	.36	14.12	.32	5.75	4.89

The cupola charge is:	Percent
No. 1 stone,	12.5
No. 2 stone,	68.75
No. 3 stone,	18.75

Recovery:

2,000 pounds raw material = 1,400 pounds loose wool.
1,400 pounds loose wool = 1,000 pounds granulated wool.

Plant capacity:

14 tons loose wool per 24 hours.

Fuel ratio:

1 coke to 2-1/2 raw material.

Cupolas:

2 - one 54 inches diameter, 8-1/2 feet high; one 36 inches diameter, 10 feet high.
Water jackets - 5- and 4-inch, full length.
Air-blast pressure, 8 ounces. Large cupola uses 120 cubic feet and small one 60 cubic feet per minute.

Slag stream:

1 stream to each cupola, 3/8 to 1/2 inch in diameter and 4 to 8 inches long.

Steam jets:

V type with legs 1-3/8 inches long and 3/32 inch wide, spread 1-1/4 inch at top.
Steam pressure, 125 pounds gage.

Oil:

Fed 18 inches beyond steam jets at rate of 55 gallons per 24 hours or 4 gallons per ton of loose wool.

Wool room:

46 feet long, 14 feet high, and 6 feet 4 inches wide. One room serves both cupolas. Conveyor floor travels 2 to 9 feet per minute. Bats are cut by hand.

Granulator:

Single roll-toothed type.

Shot removal:

Trommel, 36 inches in diameter, 9 feet long, slope 10°, speed 50 r.p.m. Screen, 12-mesh. Stationary screen, 45°, 4-mesh cloth.

Steam generator:

Surmounting the large cupola and built integral with it is a 60-horsepower boiler containing 80 two-inch firetubes. The firebox is a continuation of the water jacket of the cupola.

Plant 22

Raw materials:

Regular lime-boro-silicate glass mix. The proportions of ingredients are changed from time to time as required for the variety of types of wool fiber desired.

Fuel ratio:

Natural gas with a 1,000 B.t.u. rating is used at the rate of 16,000,000 B.t.u. per ton of glass wool.

Plant capacity:

50 tons of wool per 24 hours.

Cupolas:

None. The raw materials are melted in two regenerative-type glass tanks. One tank has a capacity of 100 tons, the other 60 tons. Refractory clay lining is used.

Slag stream:

The glass from the tank is fed through a throat over a forehearth to bushings having plates with fine perforations. The bushings are heated electrically. Fine streams of molten glass passing through the perforations are attenuated by steam pressure and blown into wool. The steam breaks up the glass stream within the perforated plates and blows it through metal snouts or inverted funnels to the conveyor belt.

The temperature of the glass ranges from 2,100° to 2,600° F. This again is determined by the type of wool being blown.

Wool room:

The wool room in this process consists of the blowing snouts and a forming hood approximately 3 by 6 feet in vertical section and 4 feet wide horizontally. The bottom of the hood consists of a conveyor belt, which carries the wool to the fabricating plant.

Granulator:

Blade-type grain cutter.

Plant 23

Raw material:

Argillaceous shale and limestone tempered with a high calcium limestone.

Typical analyses are:

	Shale	Limestone	Wool
SiO_2	24.53	39	44.88
Al_2O_3	11.61	2	10.88
Fe_2O_3	2.66	1.5	.72
CaO	20.85	22	32.76
MgO	9.99	6	8.63
SO_3	1.26	--	--
Loss on ignition	29.07	28	--

The high-calcium limestone averages 98 percent $CaCO_3$.

Cupola charge:

Argillaceous limestone, 245 pounds; limestone, 115 pounds; high-calcium limestone, 40 pounds.

Recovery:

From 1,000 pounds of raw material there is made 660 pounds of loose wool, which in turn produces 460 pounds of granulated wool.

Fuel ratio:

90 pounds of coke to 400 pounds of raw material.

Cupola:

1 - 36-inch-diameter by 8 feet high with a 6-inch water jacket.
Temperature - melting 3,000° F., blowing 2,550° F.
Hydrant pressure on water jacket, 20 pounds to the square inch.

Tuyeres:

Five 6-inch tuyeres located 18 inches above the bottom of the cupola. The cupola uses 900 cubic feet of air per minute at a pressure of 2 or 3 inches water gage.

Tap hole:

Firebrick and carborundum made up with high-test fireclay.

Slag stream:

The slag stream from the tap hole falls 6 inches to a steel-plate flat lip 8 inches wide. This lip is cooled by air through a jacket and splits the slag stream into two small streams 3/8 inch in diameter, which fall 4 inches to the steam jets.

Steam jet:

The steam nozzle is of the ordinary V type flat face with 2-inch legs spread 1 inch at the top and with slots 0.05 inch wide. There is a single small center hole near the apex of the V. The steam pressure is carried at 120-pound-gage pressure. 2,000 pounds of steam are used per hour.

Wool room:

The wool room is 40 feet long, 6 feet wide, and 25 feet high. The floor is composed of a pan conveyor operating at a speed range of from 2 to 3 feet per minute. The room is ventilated at the top with an exhaust-fan dust collector.

Granulator:

The granulator is a feed-chopper type and feeds to a trommel for shot removal consisting of 2 cylindrical screens, one 36 inches in diameter with 3/8 inch mesh and the other 48 inches in diameter with 1/2 inch mesh. The trommel operates on a slope of 8 inches in 12 feet at 20 r.p.m.

Plant 24

Raw material:

Blast-furnace slag, dolomite, and sandstone.
Cupola charge: 200 pounds of slag, 20 pounds of dolomite, and 20 pounds of sandstone.
Typical analyses follow:

	Slag	Dolomite	Sandstone
SiO_2	36.40	0.77	99.7
Al_2O_3 and Fe_2O_3	15.46	.83	-
CaO	38.64	30.60	-
MgO	6.20	20.45	-
S	1.84	.10	-
Mn	.34	-	-
CO_2	-	46.08	-

Plant capacity:

7 to 9 tons per 24 hours.

Recovery:

1,000 pounds of raw material = 700 pounds of loose wool.
700 pounds of loose wool = 500 pounds of granulated wool.

Fuel ratio:

1 coke to 3 raw materials.

Cupola:

1 - 36-inch diameter by 6 feet 6 inches high with a 3-inch water jacket.
Temperature - melting 2,750° F., blowing 2,600° F.
Tuyeres - seven 4-inch tuyeres place 16 inches above the floor of the cupola.
Air pressure - 3 ounces gage. Air is supplied by American Blower Co. blower 7P type, no. 759.
Water is used in the water jacket at hydrant pressure.

Tap hole:

Water-jacketed welded-steel plate, 8 inches square with a 2-inch round orifice in the center. The orifice is plugged with clay or mineral wool.

Slag stream:

3/4 inch in diameter and drops 6 inches to a cast-iron spreader plate, which breaks the stream into two, one to each side. The diameter of the slag stream at the tap hole is 3/4 inch and at the steam jet 1/4 inch.

Steam jet:

V type with legs 1-7/8 inches long, spread 1-1/8 inches at the top, with a slot slightly larger than 1/32 inch in width. Steam is supplied by a 50-horsepower boiler at a pressure of 100 pounds gage.

Wool room:

52 feet long by 12 feet high by 6 feet wide. The floor of the wool room consists of a 1/4-inch-mesh screen conveyor operating at 2 to 4 feet per minute.

Granulator:

Cotton-picker type.

Shot removal:

48 inch by 10 foot trommel set on a slope of 1 foot in 12 and operating at 60 r.p.m. The trommel is covered with 1/4-inch screen cloth. A light paraffin oil is sprayed on the wool 18 inches ahead of the steam jet at the rate of 2 gallons per ton of wool.

Plant 25

Raw material:

Calcareous shale.
Typical analysis of the shale and wool follows:

	Shale	Wool
SiO_2	24	40
Fe_2O_3	2.5	1.34
Al_2O_3	18.1	14.86
CaO	21.1	31.46
MgO	4.6	11.69
Loss on ignition	28.8	.2
Sulfur	.4	.1

Recovery:

From 1,000 pounds of raw material, the plant produces 660 pounds of loose wool, from which 360 pounds of shot-free wool is obtained. The difference of 300 pounds, however, is composed of shot and wool fibers. These are returned to the furnace and remelted for wool; hence, the recovery is in the neighborhood of 65 percent, although not accomplished at one heat.

Fuel ratio:

In 1938 the average electric current required per ton of wool manufactured was 2,500 kilowatt-hours.

Plant capacity:

Plant capacity is 4-1/2 tons per day.

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Cupolas:

No cupolas used.

Electric furnaces:

This plant uses three 100-kw. electric furnaces. These furnaces are circular in form, 5-1/2 feet outside diameter, and 3-1/2 feet inside. They carry a molten bath 1 foot deep, or a 1-ton melt. The process is essentially a batch process. Three-phase, 600-ampere, 135-volt current is supplied through three 4-inch graphite electrodes immersed in the bath. Silicon carbide refractory is used for furnace lining. The melting temperature is 2,800° F. and the blowing temperature 2,400° F.

The tap hole is a cast-iron trough-shaped lip 2 feet long from the molten material to discharge point.

Slag stream:

The slag stream is approximately 1/4 inch in diameter to the point where it contacts a spinning disk.

Steam jet:

No steam is used in this plant for blowing. The slag stream falls on a spinning disk operating at high speed, which breaks up the stream into fine globules and propels them through the air, forming wool in a manner similar to the action of the steam jet in other wool-manufacturing plants. The disk is made of alloy steel and the outer section of the periphery has several concentric ridges. These receive the slag stream.

Spinner room:

The spinner room is a sheet-iron box roughly 7 feet square and 5 feet high. Glass windows are provided in one side, through which the operator can observe the action of the spinning machinery at all times. By proper mechanism he can change the point of contact between the slag and disk at will.

The wool is drawn from the spinning disk past a horizontal vortex leading to a suction fan. The wool is drawn through the vortex and connecting pipe, and the shot and coarse fiber are thrown beyond and returned to the furnace.

Wool room and shot removal:

The wool drawn by the fan from the spinner is conducted through a sheet-iron pipe to the wool room proper, where it drops vertically from the ceiling to an inverted cone, where currents deflect the lighter wool fibers from the cone into the room and all shot and dirt are collected in the cone. The wool rooms are floored with

1/2-inch-mesh wire screen, and any shot escaping the inverted cone are shaken through and removed from below the floor.

Bats:

The wool is removed by hand to a specially manufactured Proctor & Schwartz textile bat machine, where it is compressed into bats. In the initial stages in the machine the wool is delivered by hand to a hopper and automatically weighed, each batch being tripped to a series of picker rolls similar to cotton pickers, and thence it passes to an inclined slat belt, which delivers to a cross belt at the proper thickness for bat manufacture. The bats are cut longitudinally by circular saw disks and crosswise by an electrically operated disk moved by hand. Paper is fed underneath the wool on the bat conveyor.

OPERATING TECHNIQUE

While individual plant practices cannot be analyzed in this paper for the reasons given, certain interesting generalizations and comparisons may be made.

Cupolas range in size from 26 to 72 inches in diameter and 7 to 16 feet in height. Water jackets range from 3 to 6 inches in thickness. Circulating water pressure ranges from 25 to 100 pounds per square inch, and the quantity used from 25 to 50 gallons per minute per cupola.

Melting temperatures are estimated to range from a low of 2,100° to a high of 3,400° F. The average for a number of lead-slag plants was 3,350° F., for rock-wool plants 3,070° F., and for iron-slag plants 2,900° F.

Blowing temperatures range from 2,000° to 2,850° F., with iron-slag plants averaging 2,629°, rock-wool plants 2,592°, and lead-slag plants, 2,233° F.

Blast air pressures range from 1.7 ounces to 1-1/2 pounds per square inch. The quantity of air used ranges from 60 to 1,200 cubic feet per minute per cupola, or from 6 to 86 cubic feet per pound of loose wool. Blast air is introduced to the cupolas from 4 to 24 inches above the cupola floor.

The majority of present plants draw slag from cupolas in a single stream, although some use two streams per cupola and others use three. The tendency is to increase cupola capacity by increasing the number of slag streams. The diameter of the slag stream at the point at which it is cut by the steam or air jet ranges from 1/4 to 3/4 inch, but 1/4 to 3/8 inch seems to be preferred. The distance the slag is permitted to drop to the blowing nozzle ranges from 3 to 15 inches. In some plants this distance is varied for the type of wool desired.

Most plants use the conventional V type of blowing nozzle. In a few plants a U-shaped orifice is used, and others use shapes developed locally. The area of orifice opening ranges from 0.075 to 0.84 square inch.

While most plants use steam for blowing, a few are using compressed air. Steam pressures range from 45 to 125 pounds per square inch and air pressures from 50 to 95 pounds. One operator informed the author he had experimented with steam pressures up to 250 pounds per square inch but found that under his conditions pressures higher than 100 pounds gave no appreciable advantage either in quantity or quality of wool.

Using Napier's[5/] approximate rule for calculating the quantity of steam flowing from a round orifice and applying this to the nozzle orifices as used, the author calculated that the steam used for blowing wool ranges from 0.077 to 1.36 pounds per second or from 0.17 to 7.0 pounds per pound of loose wool. Assuming a pound of steam at atmospheric pressure to occupy 26.83 cubic feet, the volume used ranged from 4.5 to 188 cubic feet per pound of wool.

Where air is used, the quantity reported ranges from 7.6 to 50 cubic feet per pound of wool.

The quantity of light paraffin oil used to oil the wool ranges from 1/2 to 10 gallons per ton of loose wool. Some plants, however, do not oil the wool.

The following analyses of fiber diameter of seven commercial wools were made at the Bureau laboratory. The seven samples were selected at random and show a wide range in fiber size. In each analysis 30 fibers were measured under the microscope.

Sample no.	Type of wool	Diameter of fiber in microns[1/]			
		Average 30 fibers	Average 10 smallest	Average 10 medium	Average 10 largest
1	Glass	15.7	9.0	15.2	22.8
2	do.	13.7	6.6	12.6	21.8
3	do.	7.7	7.0	7.6	8.6
4	Rock	7.2	2.6	8.0	14.4
5	do.	6.2	2.4	5.7	11.3
6	Slag	4.4	1.5	3.9	7.8
7	Rock	3.4	1.3	2.8	6.1

[1/] 1 micron is 0.00004 inch, approximately.

[5/] Let F = the flow of steam in pounds per 24 hours,
p = gage pressure,
a = atmospheric pressure,
A = area of orifice in square inches,
P = absolute pressure = p + a,
then F = 1234.3 PA.

A rough comparison of length of fiber in these seven samples showed samples 1, 2, 4, 5, and 6 to be composed of fibers less than 2 inches long. Sample 7 had no fiber over 1 inch in length. The fibers of sample 3, on the other hand, were extremely long, running as much as 18 inches.

Fryling[6] and Plummer[7] discuss the range of chemical composition of furnace charges possible for blowing suitable mineral wool in considerable detail. Analyses of furnace charges used at plants visited by the author show the ratio of acid to base to range from 1.5 acid: 1 base to 1 acid: 2.2 base. In lead-slag plants the average ratio of acid to base was 1.2 to 1. In iron-slag plants it was 1.1 to 1 and at rock wool plants 0.93 to 1.

A study was made of the ratio of raw materials to loose wool recovered, of raw materials to granulated wool, and of coke to raw materials, all calculated on a weight basis. The average results were as follows:

	Wool from -		
	Lead slag	Iron slag	Rock
Raw materials to loose wool	1-0.76	1-0.88	1-0.63
Raw materials to granulated wool	1-0.5	1-0.62	1-0.43
Coke to raw materials	1-4.3	1-2.26	1-2.46

Stated differently, the average recovery, in pounds, from 1,000 pounds of raw materials was reported to be:

From -	Loose wool	Granulated wool	Shot loss
Lead slag..	760	500	260
Iron slag..	880	620	260
Rock.......	630	430	200

DISCUSSION OF THE INDUSTRY

Economics

Mineral wool is made by melting a suitable mixture of raw materials in a cupola or other type furnace, drawing off the molten material, and subjecting it while molten to the disintegrating effect of steam or air under high pressure. The steam or air jet breaks or shears the molten slag stream into tiny globules and propels them through the air at high speed. In their flight they are drawn into minute fibers, the phenomenon being analogous to a comet and its tail. The wool fibers are then "granulated" and the shot removed by screening. The loose wool, before granulation, is fabricated into many and varied insulating materials. Granulated wool is less-suited for fabrication because the fibers have been broken.

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[6] Lamar, J. E., and others, Rock Wool from Illinois Mineral Resources: Illinois Geol. Survey Bull. 61, 1934.

[7] Plummer, Norman, Rock-Wool Resources of Kansas: Kansas Geol. Survey Mineral Resources Circ. 5, 1937, p. 74.

From the preceding summary it would seem that the manufacture of mineral wool is a comparatively simple process. In a sense this is true, for mineral wool as such can be made without a great deal of technical knowledge. The Illinois Geological Survey is quoted[8] as estimating that $50,000 to $60,000 is enough capital to build and equip a manufacturing plant capable of producing 1,000 pounds of wool per hour, and the writer has seen plants that undoubtedly were started on less.

Mineral wool is a bulky material (usually not more than 12 tons can be packed in a freight car) and as such is expensive to ship long distances.

The manufacture of good wool formerly implied the necessity of a supply of natural-wool rock or iron blast-furnace slag, thereby confining production to certain localities. The rapid growth of the industry has shown that wool can be made from a great number of raw materials, thus permitting decentralized production.

To the initiate, these factors point to future production of mineral wool from small, comparatively inexpensive, local manufacturing plants or to what may be called a "poor man's industry." The author subscribes to this thought in part only.

It is probably true that centers of dense population will support plants of large capacity; a recent news article reported a single order for 3,500,000 square feet of 2-inch mineral-wool insulation to be used in a huge building project in a metropolitan area. The rapid growth of the industry in the past decade has created a highly competitive situation in spite of the fact that manufacturing capacity may or may not have reached the saturation point. Increased familiarity of the purchasing public with the potentialities of mineral wool has initiated inquiry into its technical possibilities and its applicability for different purposes. This, in turn, has accelerated demands for products that would satisfy certain specific conditions. This is evidenced by the greater demand for specification products. The older manufacturers have recognized this and have met it by instigating technical study of their products and processes with the object of standardization or improvement.

From his study of the industry, the author believes that the manufacture of mineral wool will continue to be a so-called decentralized industry because of transportation costs and the wide distribution of potential raw materials. On the other hand, while the majority of future local plants will be comparatively small, they must be highly technical to meet the market demands for specification products. In support of this opinion is the fact that recently several plants have been closed and plans for others, contemplated by large well-financed organizations, have been abandoned.

The manufacture of mineral wool to meet specifications within rapidly narrowing limits is not a simple process and cannot be accomplished without detailed and elaborate technical control.

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[8] Pit and Quarry, vol. 29, No. 10, April 1937, pp. 75-76.

An important advantage advantage of mineral wool when used as home insulation is its fire-retarding properties. The National Bureau of Standards[9] reports the following results of fire-penetration tests on bearing and nonbearing walls of different types of construction.

Material	Thickness of facings (plaster or board), inches	Filling		Fire-endurance period	
		Form	Density, lb./in.^{2}	Bearing, hour	Non-bearing, hour
T & G 3-in. wood ceiling boards	3/4	Bulk, tamped	6.9	1/4	1/4
Do.	3/4	Bulk, loose	2.7	1/4	1/4
Do.	3/4	Bulk, hand-packed	2.6	1/2	1/2
Wood lath, lime plaster ..	1/2	Pellets, blown in	2.2	---	3/4
Gypsum board	1/2	Bats, not nailed	0.6 to 1.2	3/4	1
Do.	1/2	Bats, nailed	.6 to 1.2	1	1
Wood lath, gypsum plaster	1/2	Bats, not nailed	1.0 to 1.3	1	1
Do.	1/2	Bats, nailed	1.0 to 1.3	1	1
Metal lath, gypsum plaster	3/4	Bats, 2/3 nailed	1.0 to 1.3	1-1/2	1-1/2

Research

In further support of the opinions advanced, it is pertinent to indicate those items in the manufacturing process that require careful technical study and control by an established producer and that hold potential trouble for the prospective producer. They are, in part, as follows:

1. Chemical and physical composition of raw materials.
2. Type of melting furnace.
3. Melting and blowing temperature.
4. Blowing technique.
5. Shot prevention or removal.
6. Consumer's specification requirements.

Raw Materials

A great many materials are used in the manufacture of mineral wool today, among them being the natural so-called wool rock of Indiana, classed by Cummings and Shrock[10] as a calcareous shale or argillaceous limestone; common shale; clay; combinations of calcareous and siliceous materials, including waste glass and china; and iron, copper, and lead blast-furnace slags. Besides these, the Illinois Geological Survey[11] suggests the possibility of manufacturing wool from charges containing sand and gravel, common clay, or other unconsolidated materials when operating technique has perfected processes to use them. That this has been done already is evidenced in the description of individual plants elsewhere in this circular. At one plant the author was shown a sample of black wool said to have been made from fly ash.

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[9] National Bureau of Standards, Technical News Bull. 259, November 1938.

[10] Cumings, E. R., and Shrock, R. R., the Geology of the Silurian Rocks of Northern Indiana: Indiana Geol. Survey Pub. 75, 1928.

[11] Lamar, J. E., and others, work cited in footnote 6 (p. 38).

Unconsolidated fine materials cannot be used in water-jacketed or brick-lined cupolas because of the difficulty of forcing a draft through them. This confines the selection of raw materials for cupola melting to products in sizes large enough to permit free passage of furnace gases. In addition, it is necessary that the material retain its shape to the melting zone.

The greatest variation, however, lies in the chemical composition of the raw material. This has been interestingly presented by Lamar and others[12] and by others in the technical press and need not be discussed further here except briefly. A study of the chemical composition of raw materials used in the individual plant descriptions will show the great variety used. Some operators attempt to achieve and maintain a chemical balance between acids and bases in the cupola charge. Others contend that this is not necessary and that better wool is obtained when there is a definitely greater percentage of acids than bases, or vice versa. The author is not prepared to support either contention, being content to record what is being done at different plants and to point out that similar chemical compositions in the cupola charge may be obtained by combining two, three, four, or more of a large number of natural or waste materials, and that the chemical composition of the charge is reflected in the chemical composition of the wool.

The large number of combinations possible is at once an incentive to the use of local materials and at the same time a warning to the prospective new producer.

Type of Melting Furnace

By far the largest portion of our present production of mineral wool is made in water-jacketed cupolas. The original brick-lined cupola has almost disappeared, although it is understood a few are still in use. Cupolas require raw material in lump form to permit the passage of furnace gases. It should be mentioned, however, that at least one manufacturer has been successful in briquetting fine unconsolidated materials and melting them in cupolas, and one operator is using a conical cupola instead of the cylindrical type that had become more or less standard.

Recently, the reverberatory-type furnace with oil fuel has been used successfully in the manufacture of wool, and glass wool is being made in a similar furnace. This equipment permits the use of finely divided unconsolidated materials, since it is not necessary that furnace gases pass through them. Shot constitute an appreciable waste in the manufacture of wool with cupolas, but with the reverberatory type of furnace they can be remelted to make more wool.

The electric furnace has been utilized at one plant and is reported to be in use at another. Powdered coal has been reported as being used at one plant and natural gas in others.

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[12] Lamar, J. E., and others, work cited in footnote 6 (p. 38).

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It is evident that the type of melting furnace that will be used in the future is still a matter of scientific research, experiment, and evolution. Possibly none of the present types of equipment will be the ultimate standard. The proper operation of either the old or a new type, however, requires expert knowledge and cannot be left safely to inexperienced operators.

Melting and Blowing Temperatures

Few mineral-wool producers can tell accurately the temperature maintained in their melting zones. This is due primarily to their inability to determine it. Apparatus for determining these high temperatures is expensive and requires expert knowledge in its manipulation. In some instances temperatures are determines by thermocouples in the furnace wall or near the melting zone, and the actual melting temperature is calculated therefrom.

The blowing temperature or temperature of the issuing slag stream is also difficult to measure accurately. It is largely gaged by color and for that reason is subject to the ability of different people to detect color.

Both melting and blowing temperatures are important factors in wool manufacture. With the same raw materials or chemical composition of furnace charge and with all other factors remaining constant, a change of melting or blowing temperature, or both, will produce wool of considerably different physical characteristics, such as shot content, fiber diameter, fiber length, etc. All these have a definite bearing on the ever-present economic problem.

A change in chemical composition or physical characteristics of the furnace charge may require a radical difference in melting temperature, whereas better wool may result without change in the original blowing temperature.

The effect of difference in blowing temperature is easily demonstrable by varying the length of drop of the slag stream from tap hole to steam jet. Some operators have found that a certain type of wool is blown from their cupolas with a 4-inch drop; and with an 8- or 10-inch drop the result is a radically different wool.

Melting and blowing temperatures have definite effects on the viscosity of the slag. Chemical composition also affects viscosity. Apparently, slag viscosity is an important factor in the shearing action of the steam or air jet and its ability to produce fine or coarse fiber and a minimum or maximum of shot. Since viscosity depends on composition as well as temperature, it is conceivable that two slags may have the same viscosity and yet be widely different in composition. The author has been unable to learn from the experience of operators whether two slags differing in chemical composition but with the same viscosity would produce wool of comparable physical characteristics.

A study of the blowing temperatures given in the plant descriptions shows the wide variation in actual use. It is plain that different temperatures would be necessary with different ingredients in the charge, but examination will show wide variation in temperature with similar raw materials.

Undoubtedly, adequate study would discovery the reasons for these anomalies, and they may even be apparent to the blast-furnace technician; they are emphasized herein to show the necessity for adequate technical control of plant operation and possible causes for failure by the inexperienced.

Blowing Technique

Totally aside from blowing temperature, there is apparently considerable latitude in the blowing technique itself.

The length of drop from tap hole to steam jet has been mentioned as affecting temperature or being influenced by viscosity. There is a further effect, however. The farther the slag stream drops, the smaller becomes its diameter, until finally it is broken into drops by air friction. It will be noted in the plant descriptions that there is some variation in the diameter of the slag streams when cut by the steam or air jet. The diameters listed were estimated by eye only and are not actual measurements, hence there is probably even greater variation than is indicated by the figures. Obviously, the diameter of the descending slag stream is an important factor in evaluating the ability of the steam jet to shear or break it into globules.. Both viscosity and temperature are pertinent factors here, also. The author was informed by one experimenter that the farther he could drop the slag to the steam jet without cooling or destroying the continuity of the stream, the better wool he could make.

In the pioneer days, the type of blower was considered a trade secret of considerable importance. At present, the conventional V-type nozzle is used commonly, although the length and width of the slots and the angle between them is still a matter of individual preference. Some have introduced improvements by curving the nozzle face; others have recessed the nozzle to avoid objectionable air currents. A few have gone to types other than V-shape. The author was advised that a nozzle had been patented comprising an annular steam orifice, through the center of which passed the slag. This device[13] was said to have been used successfully in blowing wool, but the author did not see it in actual use. A similar type of nozzle is illustrated in U. S. Patent 2,136,158.

Some operators drop the slag stream to the center of the V, while others cause it to impinge on one leg with the thought that better shearing results. One operator informed the author that merely shifting this point of contact caused considerable difference in the type of wool blown.

The conventional angle between the slag stream and the steam jet is somewhat acute, in that the slag drops vertically and the steam jet is usually directed upward to as much as 30° above the horizontal. The circular patented steam jet previously mentioned would require that both steam and slag move in the same direction, and at one plant using a V jet the slag is diverted 45° and then thrown to the steam jet at 90°.

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[13] U. S. Patents 1,807,178 and 1,859,992.

It is notable that while most plants use steam for blowing, some use compressed air. So far as the author was able to observe, there was no noticeable difference in the wool blown by air or by steam. The drop in temperature from molten slag to atmospheric is extremely rapid,[14] but presumably anything tending to reduce that time interval shortens the time of fiber formation and increases shot content.

It will be observed, also, that steam pressures vary considerably at different plants. Presumably, steam pressure (or volume), diameter of slag stream, and slag viscosity and temperature all have a definite relation to each other.

Curious as it may seem, similar blowing practice at two plants was said to give directly opposite results. Both operators directed the steam jet so that the projected wool would strike the side of the wool room at an angle. The object in one instance was to cause the shot to strike the wool and bounce clear, letting the fiber fall separately. The object in the other was to create a swirling air current, which would carry the fiber away from the wall and drop the shot near it.

Shot Prevention or Removal

The ultimate goal of the mineral-wool producer is to blow a shot-free wool. The writer has not yet found any commercial wool that is entirely shot-free. However, samples of specially processed wool were observed in which no shot was visible to the naked eye. Samples of glass wool observed had little if any shot as such, but in several instances the ends of the fibers were enlarged and hook-shaped. On the other hand, picked samples of glass wool showed remarkable length of fiber of uniform diameter and no visible shot or fused ends. Spun rock-wool samples showed long, silky fiber with no visible shot.

Glass and spun wool are formed by processes different from those customarily used for rock and slag wool. Very likely this difference causes the difference in shot content, although chemical composition of raw materials, temperature, and viscosity may contribute.

Shot is a waste product to manufacturers using cupolas, and each pound made represents money spent in heating the equivalent raw material. Operators differ in their opinions as to exactly what increases or decreases the percentage of shot. One operator increases blowing temperature to reduce shot, but comparison of plant details indicates two or more operating on similar materials are initially wide apart in blowing temperatures and yet make wool comparable in shot content.

Presumably shot are produced as a result of the globule cooling in its passage through the air before it has been entirely converted into fiber. This suggests two remedies - (1) to manipulate the blowing operation so that smaller globules will be made and (2) to raise the speed of the particle by increasing the steam pressure. Fryling has discussed experiments in blowing and gives some interesting results.[15]

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[14] Lamar, J. E., and others, work cited in footnote 6 (p. 38).

Failing to prevent the formation of shot, operators have investigated the possibility of its removal from the wool after blowing. Raw wool contains from 10 to 30 percent shot by weight. These shot particles may range from microscopic size up to 1/8 inch or more in diameter. Obviously, caught as they are in the interlaced fibers and in many cases integral with the fiber, their separation is a somewhat difficult problem unless the fibers themselves are ground or broken. The solution of this problem has been the manufacture of granulated wool. In its preparation the raw wool is subjected to severe beating in hammer mills, feed threshers, or other types of granulators. In this process the fibers are broken up until the shot is released and can be separated by screening. Breaking the original fiber length, however, destroys much of the binding power inherent in long, interlaced fibers, which the manufacturers would like to preserve for its greater insulating value.

Experiments are being conducted by means of processes other than granulation for shot removal, which bear considerable promise of success, but the author does not feet free to discuss them. He believes, however, that in the not distant future shot-free wool can be obtained or wool in which the shot content can be specified within narrow limits and still retain the original fiber length.

CUSTOMERS' SPECIFICATION REQUIREMENTS

A few large consumers of mineral wool have demanded a product that will meet their particular specifications. These specifications, in some instances, are a matter of contract between buyer and seller and have not been made public. Specifications of different buyers do not agree, probably because the material is used for different purposes.

At present, while the demand for specification wool is increasing, no standard specifications have been evolved. Illustrative of the trend of specification requirements may be cited the following:

1. Chemical composition.
2. Shot content.
3. Fiber size (diameter and length).
4. Ductility or softness.
5. Waterproofing.
6. Thermal conductivity.

Chemical Composition

As far as the author is aware, there has been no publication of the results of experimental tests indicating what physical or other effects may be attributable directly to the chemical composition of mineral wool. He is informed, however, that such tests are in progress with the object of establishing standard specifications.

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[15] Lamar, J. E., and others, work cited in footnote 6 (p. 38).

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The two chemical ingredients that so far have caused considerable discussion are lime and sulfur. It is reported, but without published experimental test data, that mineral wool in which the percentage content of lime is too high slowly disintegrates under atmospheric conditions, the fibers become brittle, and the wool loses its resilience. After sufficient time such wool is said to settle on itself, closing the minute air spaces, and thereby reducing its insulating value. So far, no data recording experimental tests have been released showing the limits of chemical composition within which this type of deterioration takes place although it is understood such tests are now under way.

Many, if not all, blast-furnace slags contain some sulfur, although usually in small amounts. Most fuels also contain more or less sulfur. While it is true that the heat necessary in the wool cupola is sufficient to drive off the sulfur as a vapor, it is also true that chemical analyses of some wools show them to have retained small amounts of sulfur. Some operators have studied this question and have found that the sulfur in the wool may be in the form of a sulfide, sulfite, or sulfate. Without attempting to discuss in detail the chemistry involved, it is enough to point out that sulfides are produced under reducing conditions, that is, lack of oxygen. Such conditions apply in the manufacture of blast-furnace slag. Whether oxidizing or reducing conditions are present in the wool cupola probably will be determined by the quantity of air blown through the tuyeres. If enough air is present to assure oxidizing conditions in the cupola, the sulfur retained by the wool will be largely, if not all, in the sulfite or sulfate form and stable. If not enough air is present, it may appear as sulfide, which is unstable in the presence of moisture under atmospheric conditions. Acid formed from the combination of sulfides and moisture is corrosive and harmful.

It is important to know, therefore, whether a mineral wool contains sulfur and, if so, in what form.

Stead[16] is reported to have determined experimentally that wool made from slag had no corrosive effect on a bright, polished knitting needle inserted therein and subjected to accelerated moisture tests over considerable time periods.

Specifications should show the percentage of lime and sulfur present in the wool and the chemical combination in which the sulfur occurs if present.

Shot Content

Mineral wool is used for heat or sound insulation. The shot in the wool has no insulating value, and therefore its presence in wool reduces insulating value by displacing an equivalent volume of inert air space. An examination of most mineral wools will show shot present in sizes grading down to microscopic.

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[16] Stead, J. E., Is There Any Corrosive Quality in Slag?: Nat. Slag. Assoc. Symposium 10, 1928, p. 9.

Specifications should show the total percentage of shot present and the particle size as represented by 100 percent passing a certain standard mesh screen.

Fiber Size

Mineral wool is being manufactured in various fiber diameters and lengths. Theoretically, the smaller the diameter of the fiber, the greater will be the number of confined air spaces, and hence the greater the insulating value. For mechanical and other reasons, it is not practicable to manufacture wool 100 percent of which has a minimum diameter. The lower and upper limits of fiber diameter for practical or specific purposes have not been determined as yet so far as the author is aware.

The importance of fiber length also has not been established definitely. When raw wool is manufactured free of shot, fiber length will be of value as a supporting bond in retaining shape in place.

The author believes that both diameter and length of fiber will be important factors in determining the physical qualifications of different mineral wools and will find a definite place in future specifications when their proper evaluation has been standardized.

Ductility

Ductility or softness of wool is a factor for which no standards have been set as yet. Possibly "ductility" is not quite the proper term to use. The quality referred to is a combination of tensile strength and compressibility. Possibly "resilience" would be a better term. Some wools are soft to the touch while others are decidedly harsh. Presumably, this depends on the fiber diameter as much as the brittleness of that fiber. A soft wool is easier to handle and form to shape, whereas a harsh wool once formed may retain the shape better. As placed in the walls of buildings, the wool nearest the bottom is subjected to greater weight, due to compression, than that near the top of the wall. The fibers should be strong enough to support this weight without sagging, and yet the wool should be soft enough for easy handling.

It is not quite clear how this factor could be expressed in a specification. Possibly fiber size will cover it or possibly a specification covering tensile strength of wool per square inch at a specified density will express what is wanted.

Waterproofing

Some consumers demand that the wool be waterproofed. This does not refer to the paraffin oil used in the manufacture of the wool, the purpose of which is to keep down dust in handling.

Wool is "waterproofed" by several different processes; all of these are to some extent trade secrets, hence, they have not been discussed in this circular. Inquiry by the author regarding waterproofing elicited various opinions as to its desirability. The reason for the demand for waterproofed wool apparently originated from complaints of condensation in the walls of insulated houses. Occasionally houses showed evidence of condensation within walls after having been insulated with mineral wool, whereas previously there had been no such trouble. This led to the erroneous belief that mineral wool absorbed and retained moisture in the walls. From this belief sprang the demand for wool adequately treated to prevent absorption of moisture, hence the process of waterproofing. Careful studies by Teesdale at the Forest Products Laboratory, Department of Agriculture, and by Rowley at the University of Minnesota (see Bibliography) have shown the causes and preventatives for condensation in the interior of walls and that whether the wool was waterproofed or not made no difference. Condensation in wall interiors was found to be a result of improper wall construction, irrespective of whether or not insulation was used. Discussion of this phenomenon involves factors entirely foreign to the manufacture of wool, and the reader is referred to the publications by the authors cited for further information on the subject.

Waterproofing of mineral wool may be beneficial for other reasons, however; if so and if the demand for it continues, it will undoubtedly be reflected in specifications.

Thermal Conductivity

Fryling[17] discusses thermal conductivity and presents tables showing the relative values of various materials. He states:

> The conductance of rock wool varies with the over-all density of the material. As the density increases, the conductivity decreases to a minimum because of a decrease in size of the air pockets. Further increase in over-all density causes an increase in conductivity, the limit of which is the conductivity of the solid material.

Phrased differently, this means that the insulating value of mineral wool increases with an increase in density to a certain point, beyond which the insulating value decreases with further increase in density. From tables recalculated by Fryling, it would seem that this critical density point is in the neighborhood of 10 to 15 pounds per cubic foot.

Unquestionably, future specifications for mineral wool will include standards defining the insulating value in terms of density.

MINERAL WOOL AS A HEALTH HAZARD

Some mineral-wool manufacturers do not oil their wool, stating that consumers prefer it dry. In dry-wool plants there is a noticeable amount of wool dust or "fly" wool in the air. In severe cases, this has caused considerable throat and nasal irritation. This prompted the author to inquire into the possibility of mineral-wool dust being a health hazard.

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[17] Lamar, J. E., and others, work cited in footnote 6 (p. 38).

Fairhall, Webster, and Bennett[18] conducted a series of experiments in the Laboratory of Physiology, Harvard School of Public Health, and the results of their experiments are abstracted as follows:

Cats were exposed to (1) vapor that could be evolved by passing air over mineral wool at room temperature, (2) air passed through mineral wool so heated that the air current varied between 67° and 82° C., and (3) those exposed to number (1) method were further exposed for 1 hour daily to dusty atmospheres of finely ground mineral wool. Exposures were for 2 months continuously. The animals were killed and their tissues examined by pathological, chemical, and spectrographic methods.

Chemical investigations did not show any single factor of toxic importance. Spectrographic analysis showed traces of elements of toxic significance, which were obviously in the form of silicates and were mostly inert.

The amount of mercury, arsenic, and lead determined by chemical methods was insignificant from a toxicologic standpoint. Microscopic sections from the lungs, kidneys, and livers were examined. In the lungs of the cats exposed to dust, large numbers of refractile particles of silicates were found in the small bronchi, bronchioles, and alveolar ducts of all animals, and lesser amounts were found in the air sacs and connective tissue of the lung. The livers and kidneys of the animals showed no significant changes.

The chemical data do not show the existence of any hazard associated with contact with mineral wool. The histological evidence indicates no significant changes in the lungs, liver, or kidneys. However, in the dusted animals foreign-body reactions in the lungs were noted.

Dr. R. R. Sayers, chief, Division of Industrial Hygiene, United States Public Health Service, in a letter to the author states as follows:

> From some experiments we have performed, using mineral-wool fibers, we have found that particles remain in the tissue, producing an inert foreign body reaction similar to that of asbestos, and we have been considering dust from mineral wool as potentially harmful, that is, capable of producing a diffuse pulmonary fibrosis, when inhaled.
>
> We have been considering dusts that produce an inert reaction less harmful than pure silica and more dangerous than dusts which are absorbed from the tissues, such as limestone.

The results of these experiments indicate there is a definite danger from inhaled mineral-wool dust, but its action is mechanical rather than pathological.

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[18] Fairhall, L. T., Webster, S. H., and Bennett, G. A.: Jour. Ind. Hyg., vol. 17, 1935, pp. 263-75.

List of Manufacturers

Member of Industry	Home Office	Plant
*Alton Mineral Wool Co. C. K. Perrin, Sales Mgr. 1415 So. Compton Ave., St. Louis, Mo.	P. O. Box 268 Alton, Ill.	Alton, Ill.
American Gypsum Co. W. F. O'Neil	Port Clinton, Ohio	No plant
*American Rock Wool Corporation Michael Leury, Pres.	Wabash, Ind.	Wabash, Ind. So. Plainfield, N. J.
Armstrong Cork Products Co. L. E. Cover	Lancaster, Pa.	No plant
*Baldwin-Hill Co. W. H. Hill, Pres.	501 Klagg Ave. Trenton, N. J.	Trenton, N. J.
The Barrett Co. A. T. Miller	40 Rector St. New York, N. Y.	No plant
Bethlehem Steel Corporation N. L. Morell	Bethlehem, Pa.	Bethlehem, Pa.
Canadian Gypsum Co.	Toronto, Ontario	Toronto, Ontario
*Philip Carey Co. G. D. Lortz, Mgr. Rocktex Dept.	Lockland Cincinnati, Ohio	Lockland Cincinnati, Ohio
*The Celotex Corporation T. B. Munroe, V. P. T. F. Kearns	919 No. Michigan Ave. Chicago, Ill.	No plant
Cleveland Rock Wool Co.	Scranton Road Cleveland, Ohio	Cleveland, Ohio
Clifty Rock Wool Co.	Portland, Ind.	Campbellsburg, Ind.
Coast Insulating Corporation C. L. Newport, Pres.	634 S. Western Ave. Los Angeles, Calif.	Torrance, Calif.
Colonial Rock Wool Co.		Housatonic, Mass.
Cordelia Mineral Products Co. Ernest Miller	Lancaster, Pa.	Lancaster, Pa.
G. & W. H. Corson, Inc.	Plymouth Meeting, Pa.	Plymouth Meeting, Pa.

Member of Industry	Home Office	Plant
M. H. Dietrich Co.	625 Illinois Ave. Aurora, Ill.	Aurora, Ill.
Duggan Smith Corporation	1184 Nostrand Ave. Brooklyn, N. Y.	Castleton, N. Y.
*Eagle Picher Sales Co. T. C. Carter	Court and Main Sts. Cincinnati, Ohio.	Joplin, Mo. Newark, N. J.
Edwards Insulation Co. S. R. Edwards, Pres.	Temple, Tex.	Temple, Tex.
*Ehret Magnesia Manufacturing Co. A. M. Ehret, Jr., Pres.	Valley Forge, Pa.	No plant
Federal Building Materials Co.	221 Morris Plan Bldg. Tulsa, Okla.	Tulsa, Okla.
Federal Rock Wool Co. Louis Mareno	Kansas City, Mo.	Kansas City, Mo.
Fish, Ellis, Inc.	Bedford, Ind.	Bedford, Ind.
The Flintkote Co. S. H. Ralph, V. P.	50 W. 50th St. New York, N. Y.	No plant
*General Insulating & Mfg. Co. J. G. Cella, Exec. V. P.	404 Central Natl. Bank Bldg. St. Louis, Mo.	Alexandria, Ind. Dubuque, Iowa Dover, N. J.
Glendon Mineral Wool Co. Morris Caplan, Pres. Allentown, Pa.	Easton, Pa.	Glendon, Pa.
Guardian Rock Wool Co. Calendar, M. E., Pres.	Dallas, Tex.	Easley-near Ashland, Mo.
Gypsum Lime & Alabastine of Canada, Ltd.	Caledonia, Ontario	Caledonia, Ontario
Indiana State Farm	R.F.D. #2, Greencastle, Putnamville, Ind.	Putnamville, Ind.
Insulating Products Co. V. Von Schlegel	Aurora, Ill.	Aurora, Ill.
*Insulation Industries, Inc. M. L. Kuykendall, V. P.	10307 Lynden Ave. Detroit, Mich.	Detroit, Mich.

Member of Industry	Home Office	Plant
Insulation Products, Ltd.	Toronto, Ontario	Toronto, Ontario
Insulations, Inc.	Jackson, Ohio	Jackson, Ohio
Insulite Company E. H. Batchelder, Jr.	Minneapolis, Minn.	No plant
*Johns-Manville Sales Corporation P. A. Andrews, Exec. V. P.	22 E. 40th Street New York, N. Y.	Alexandria, Ind. Waukegan, Ill. Manville, N. J. Watson, Calif. Richmond, Ind.
Kentucky Stone Co. Verne C. Morgan	Heyburn Bldg. Louisville, Kentucky	Mullins, Ky.
M. L. Lee & Co.	64 E. 1st South St. Salt Lake City, Utah	Salt Lake City, Utah
Lehon Co.	44th St. and Oakley Ave Chicago, Ill.	No plant
Ludowici-Celadon Co.	104 S. Michigan Ave. Chicago, Ill.	New Lexington, Ohio
*Marblehead Lime Co. J. M. Palmer, V. P.	160 N. LaSalle St. Chicago, Ill.	Quincy, Ill.
Minfelt Insulation Co.	2234 Albion St. Toledo, Ohio.	Toledo, Ohio.
Mineral Insulation Co. Orval White, Pres.	Chicago Ridge, Ill.	Chicago Ridge, Ill.
National Gypsum Co. R. F. Burley, V. P.	Buffalo, N. Y.	No plant
National Rock Wool Corporation F. H. Colvin, Mgr.	1125 Roosevelt Ave.	Lagro, Ind.
North Vernon Rock Wool Co.	North Vernon, Ind.	North Vernon, Ind.
Northern Rock Wool Co.	Pontiac, Mich.	Pontiac, Mich.
Ohio Insulation Co.	Elbon & Cecilia St. Toledo, Ohio	Toledo, Ohio
*Ohio Valley Asphalt Co.	Starks Bldg. Louisville, Ky.	Summit, Ky.
*Owens-Corning Fiberglas Corporation J. S. Irvine G. Gregory, Gen. Sales Mgr.	Toledo, Ohio	Newark, Ohio Corning, New York

Member of Industry	Home Office	Plant
*C. W. Poe Co. C. W. Poe, Pres.	2795 E. 83d St. Cleveland, Ohio	Cleveland, Ohio
Refractory & Insulating Corporation	381 Fourth Ave. New York, N. Y.	Port Kennedy, Pa.
*Riverton Lime & Stone Co. Inc. E. I. Williams, Sales Mgr.	Riverton, Va.	Riverton, Va.
Rockfleece Corporation J. L. Johnson, Pres.	406 San Francisco St. El Paso, Tex.	El Paso, Tex.
Rock Wool Co. B. O. Paine	Oklahoma City, Okla.	Oklahoma City, Okla.
Rock Wool Products Co., Inc.	Wabash, Ind.	Wabash, Ind.
*The Ruberoid Co. W. B. Harris, V. P.	500 Fifth Ave. New York, N. Y.	Joliet, Ill.
St. Louis Fire Brick & Clay Co. J. W. Odell, Sales Mgr.	3050 E. Slauson Ave. Huntington Park, Calif.	Huntington Park, Calif.
Salem Lime & Stone Co. T. M. Cavanaugh, Sec'y-Treas.	Salem, Ind.	Salem, Ind.
Scherer & Co., H. N.	Winona, Minn.	Winona, Minn.
Seneca Rock Wool Co. I. B. Ingles, Pres.	c/o Heilmann Bros. 471 E. Market St. Tiffin, Ohio	Tiffin, Ohio
Servtex Material Co.	New Braunfels, Texas	New Braunfels, Tex.
P. J. Sonner Burner Co. Victor Mottweiler, Supt.	Winfield, Kans.	Winfield, Kans.
Southern Insulation Co.	155 8th Ave. Nashville, Tenn.	College Grove, Tenn.
Spun Rock Wools, Ltd.	Thorold, Ontario	Thorold, Ontario
*Standard Lime & Stone Co. R. F. Fahy, Mgr. Insulations Division	2000 First Natl. Bank Bldg. Baltimore, Md.	Millville, W. Va. Wabash, Ind.
*Standard Rock Wool, Inc. H. M. Shirey, Pres.	Yorktown, Ind.	Yorktown, Ind.

Member of Industry	Home Office	Plant
Superior Rock Wool Co.	Lagro, Ind.	Lagro, Ind.
*Tennessee Products Corporation F. Leake, Pres.	14 Cummins Station Nashville, Tenn.	Rockdale, Tenn.
*Therminsul Corporation E. E. Wood, Jr., Pres.	1603 Fulford Street Kalamazoo, Michigan	Kalamazoo, Mich.
Texas Insulation Co. M. C. Callander	2712 Live Oak St. Dallas, Tex.	Grand Prairie, Tex.
*Union Rock Wool Corporation C. E. Minear, Sec.	Wabash, Ind.	Wabash, Ind.
United Materials Co.	Summer Street Dallas, Tex.	Dallas, Tex.
*United States Gypsum Co. W. L. Keady, V. P.	300 W. Adams St. Chicago, Ill.	No plant
*United States Mineral Wool Co. E. F. Cusick, V.P.& Gen. Mgr.	9 St. Clinton St. Chicago, Ill.	South Milwaukee, Wis. Stanhope, N. J. (R.R.Sta.Netcong, N.J.)
United States Rock Wool Co. V. R. Elkins	40 S. Main St. Salt Lake City, Utah	Sandy, Utah
V. V. V. Brick & Tile Co.	Neodesha, Kans.	Neodesha, Kans.
Weber Insulations, Inc. F. Elizer, Sales Mgr.	East Chicago, Ind.	East Chicago, Ind.
Weber Insulation Products Co. Elger Secrist, Mgr.	2454 E. 52d St. Los Angeles, Calif.	Los Angeles, Calif.
*Western Rock Wool Corporation B. B. Williams, Pres.	701 No. Broadway Huntington, Ind.	Huntington, Ind.
White Bros. Smelting Corporation C. B. White, Pres.	Bridesburg-On-The-Delaware	Philadelphia, Pa.
Zier Products Co. E. M. Zier, Pres.	New Albany, Ind.	New Albany, Ind.

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*Member of the National Mineral Wool Association.

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